
# The Use of Multiple Technology Measurements to Diagnose Weapn Chamber Pressure Measurement Anomalies in Piezo-Electric Pressure Transducers

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# Vital Importance of Chamber Pressure Measurement to US Army Weapons Development

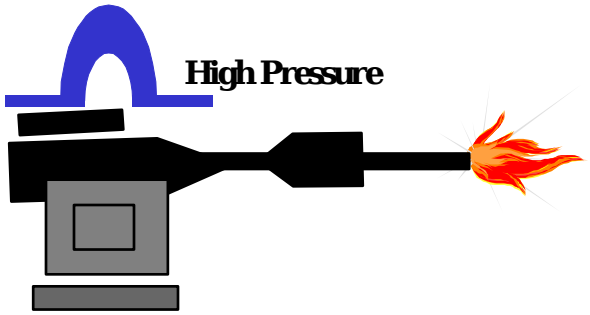
- Used for critical decsions between crew safety and combat effectiveness
- A 2% error causes:
  - 6% change in fatique life
  - 4% change in range
  - 3% change in weight
- It is currently the most demanding voltage amplitude measurement made with ballistic instrumentation

# Technical Objectives

- LONG TERM GOAL:  IMPROVE CHAMBER PRESSURE MEASSUREMENT ACCURACY BY A FACTOR OF 20X (FROM $\pm$2% TO $\pm$0.1%)  i.e. MAKE PRESSURE AS CONSISTENT AS VELOCITY

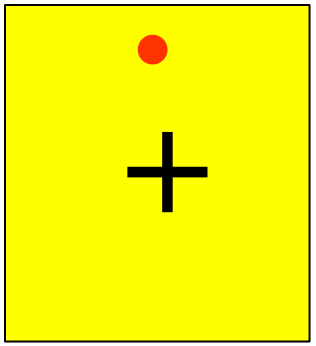
- SHORT TERM GOAL: MAKE EFFECT OF 65 GRAM CHANGE IN 8.6 Kg CHARGE WEIGHT  (AS DONE IN PROPELLANT ASSESSMENT TESTING) MORE SIGNIFICANT THAN THE EFFECT OF EXCHANGING TRANSDUCERS ( BOTH ABOUT 1%)

# BALLISTIC CORRECTIONS

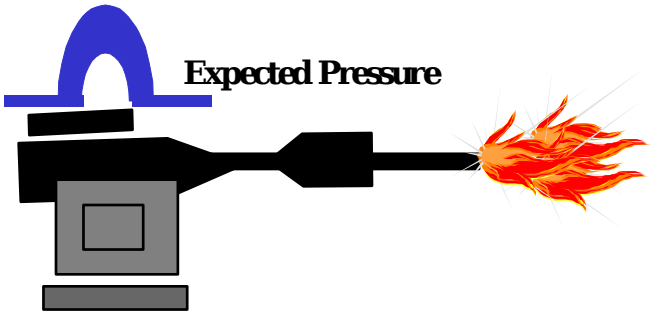



"New" (Tight Fitting) Gun

*High Velocity*

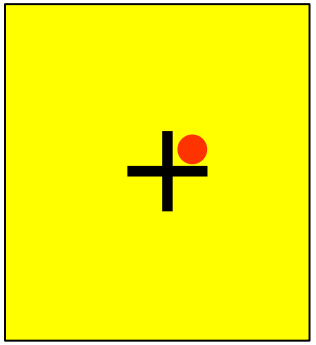


Hits Above Target

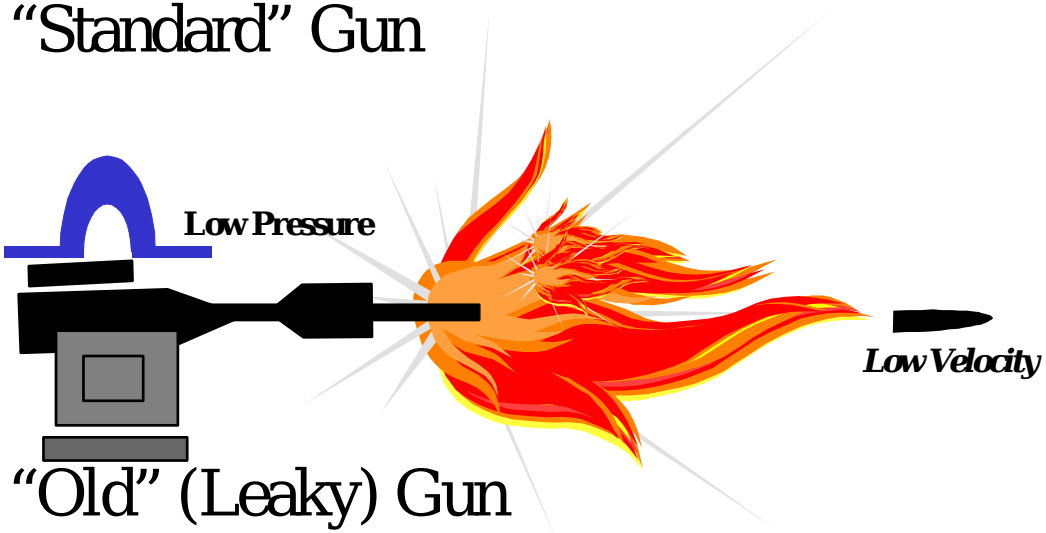



"Standard" Gun

*Expected Velocity*

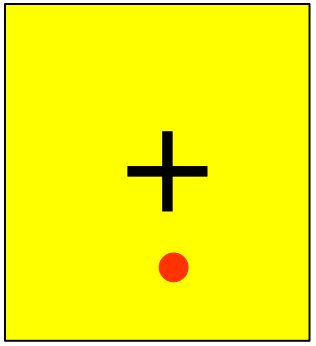


Hits On Target




*Low Velocity*

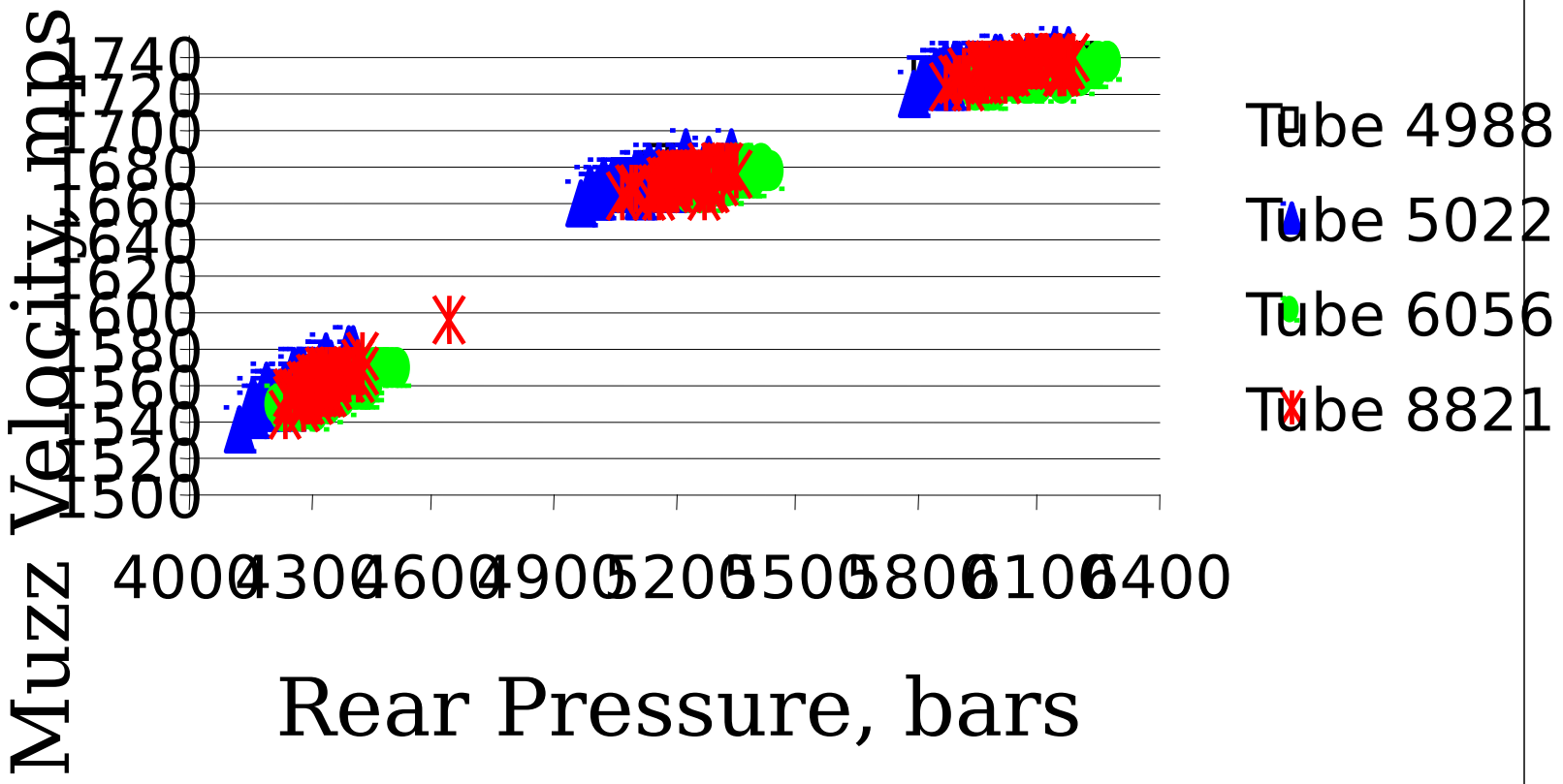
"Old" (Leaky) Gun



Hits Below Target

# CONTROL RDS: ALL TEMPERATURES

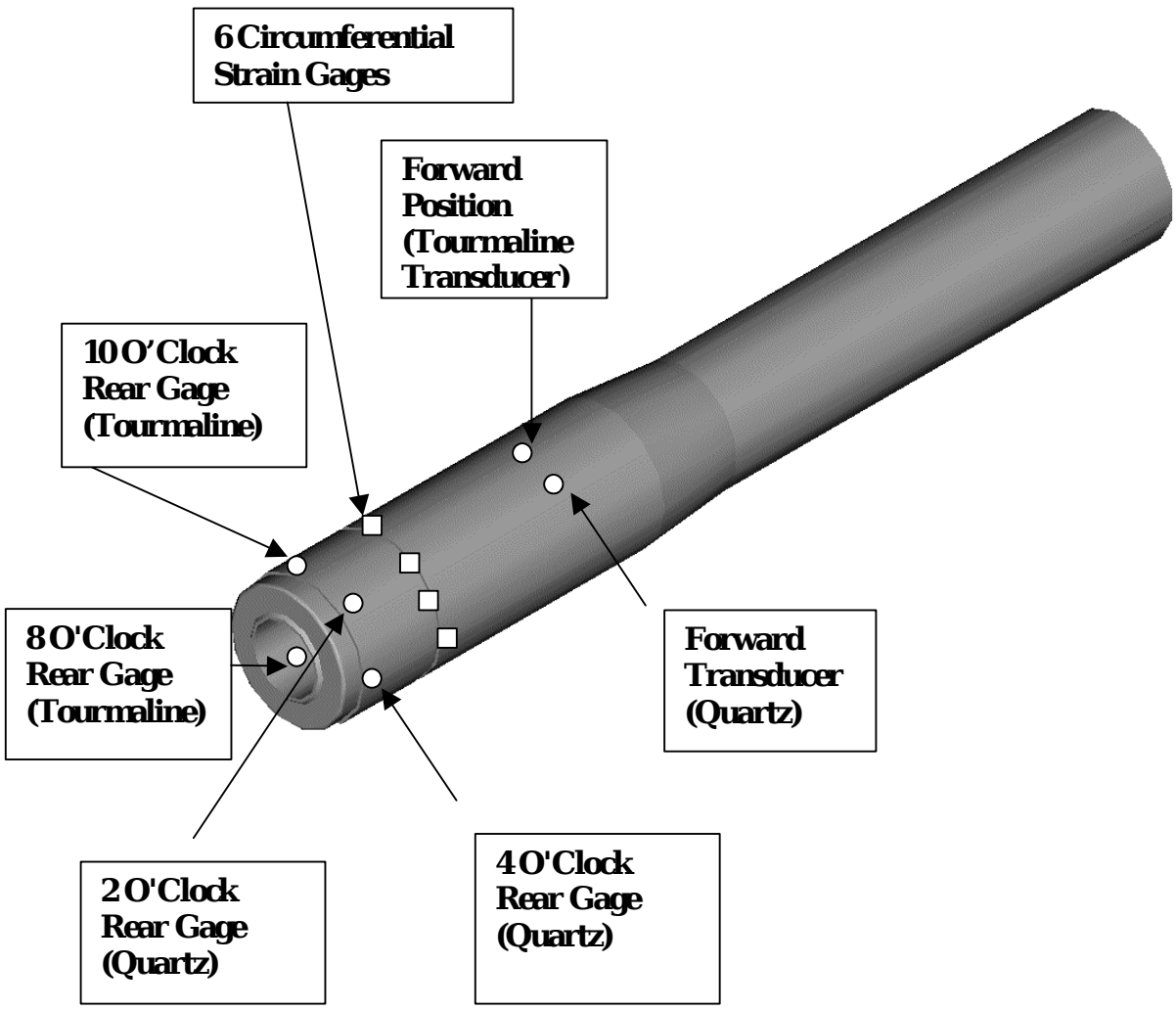
## 1996-1998

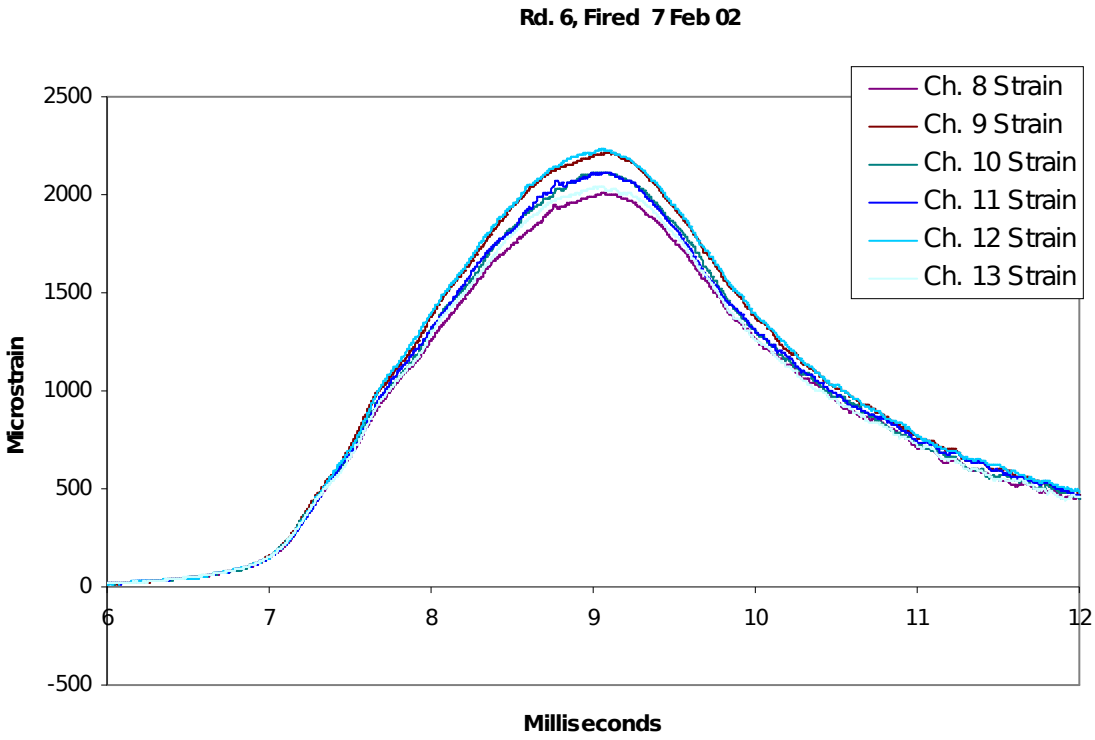


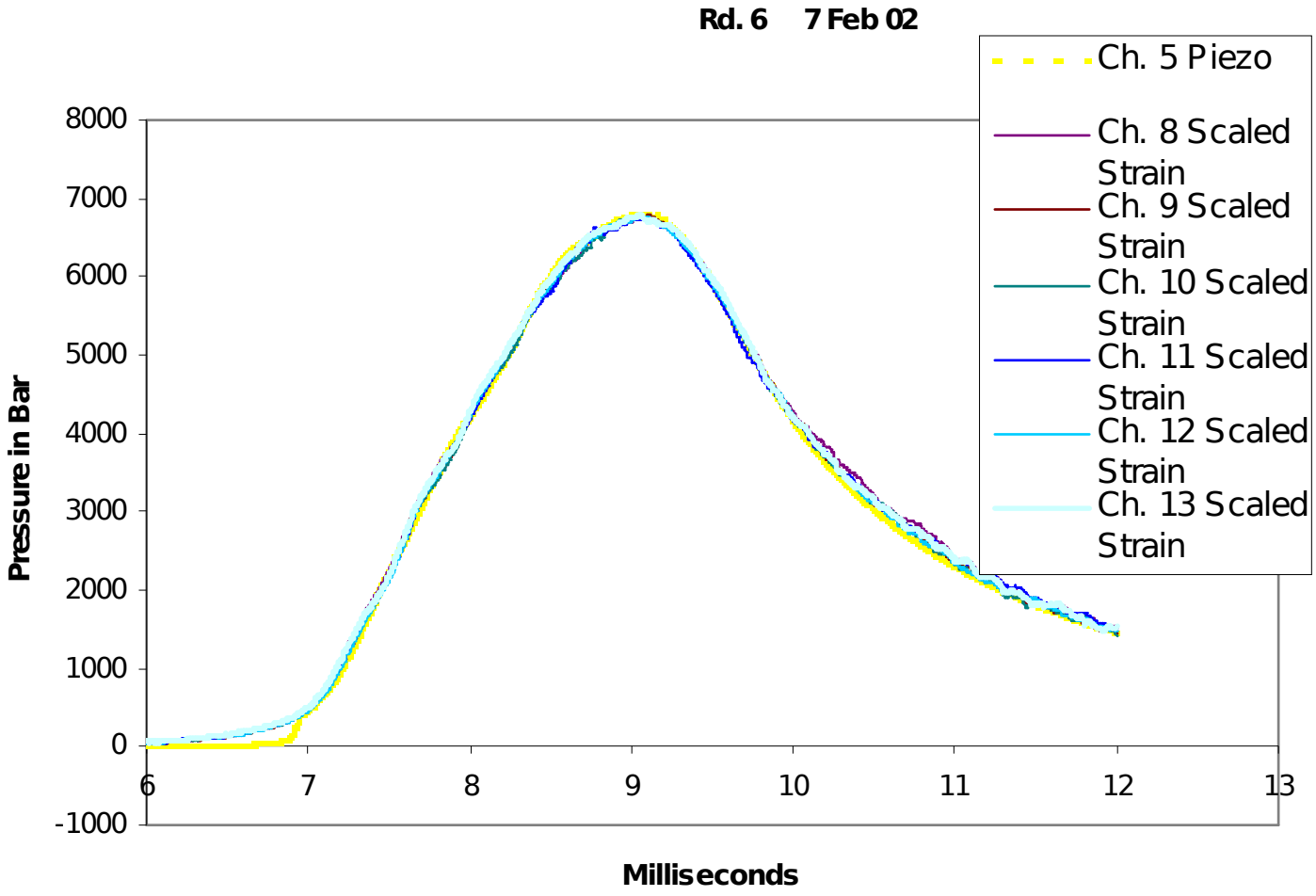
# Unusually Consistent Ammunition Lots

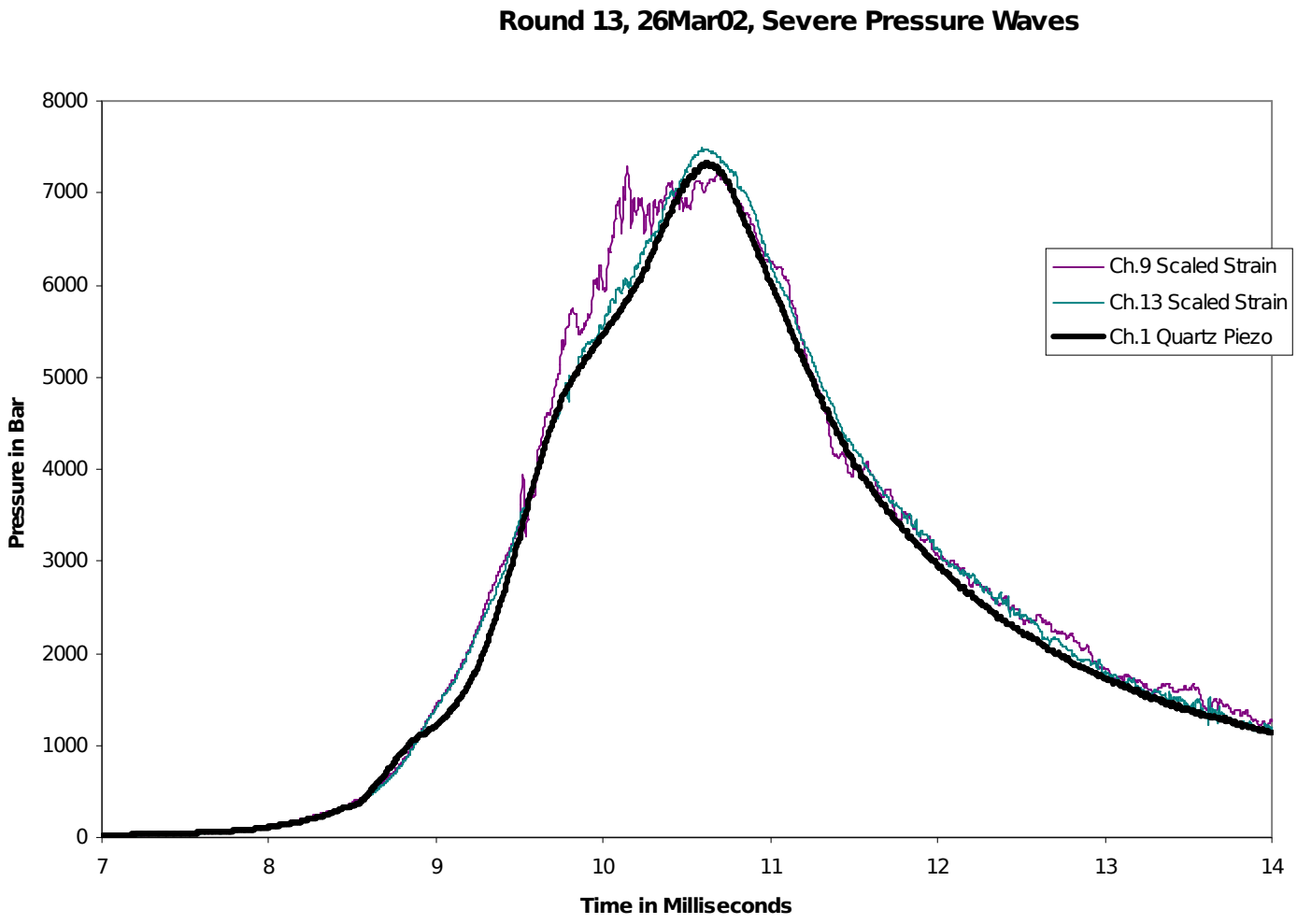
## 1995-1998 Data

| | | | |
|---|---|---|---|
| Tube | Pressure | Velocity | N |
| 8821 | 5223.36 | 1671.434 | 45 |
| 6056 | 5349.32 | 1670.488 | 25 |
| 5022 | 5150.75 | 1671.505 | 77 |
| 4988 | 5215 | 1670.513 | 24 |
| | | | |
| Mean | 5234.608 | 1670.985 | |
| Std. Dev. | 83.07025 | 0.560496 | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| Gage | Pressure | Velocity | N |
| 275 | 5311.167 | 1669.7 | 6 |
| 305 | 5198.333 | 1671.908 | 12 |
| 304 | 5152.167 | 1668.533 | 6 |
| | | | |
| Mean | 5220.556 | 1670.047 | |
| Std. Dev. | 81.79621 | 1.714082 | |


6 Circumferential Strain Gages
Forward Position (Tourmaline Transducer)
10 O'Clock Rear Gage (Tourmaline)
8 O'Clock Rear Gage (Tourmaline)
Forward Transducer (Quartz)
2 O'Clock Rear Gage (Quartz)
4 O'Clock Rear Gage (Quartz)

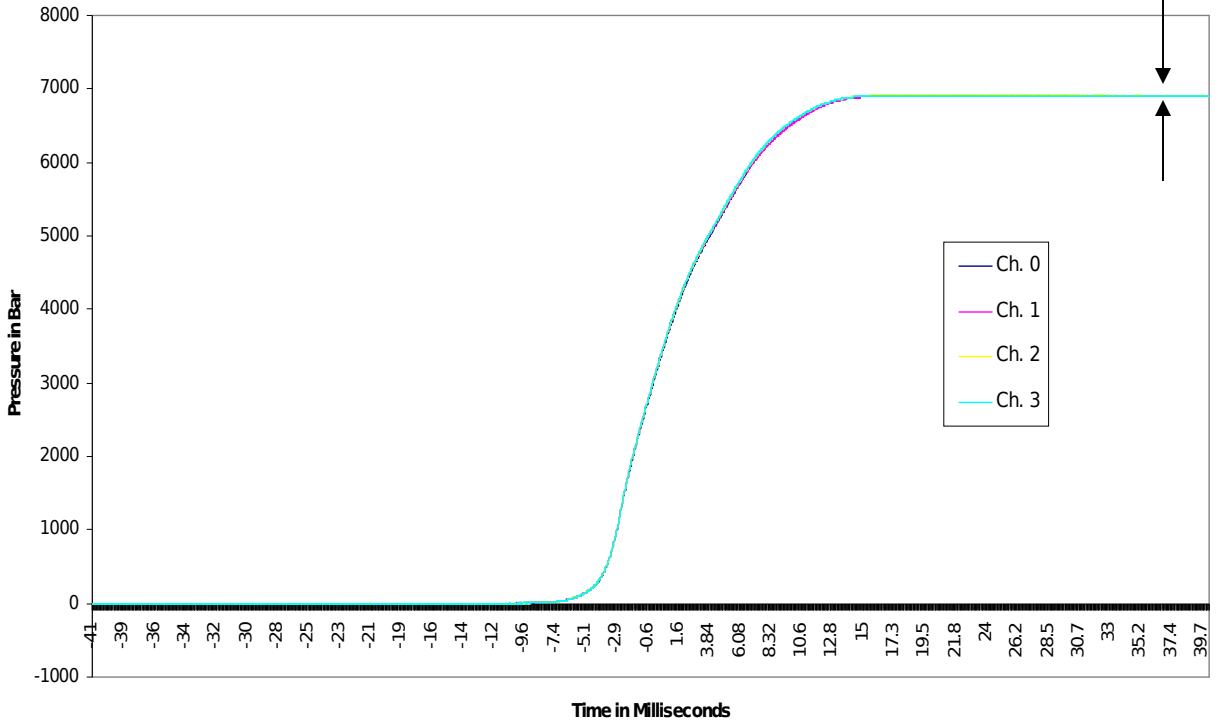

Rd. 6, Fired 7 Feb 02
Ch. 8 Strain
Ch. 9 Strain
Ch. 10 Strain
Ch. 11 Strain
Ch. 12 Strain
Ch. 13 Strain
2500
2000
1500
1000
500
0
-500
Microstrain
6
7
8
9
10
11
12
Milliseconds


Rd. 6 7 Feb 02
Ch. 5 Piezo
Ch. 8 Scaled Strain
Ch. 9 Scaled Strain
Ch. 10 Scaled Strain
Ch. 11 Scaled Strain
Ch. 12 Scaled Strain
Ch. 13 Scaled Strain
Pressure in Bar
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
6
7
8
9
10
11
12
13
Milliseconds

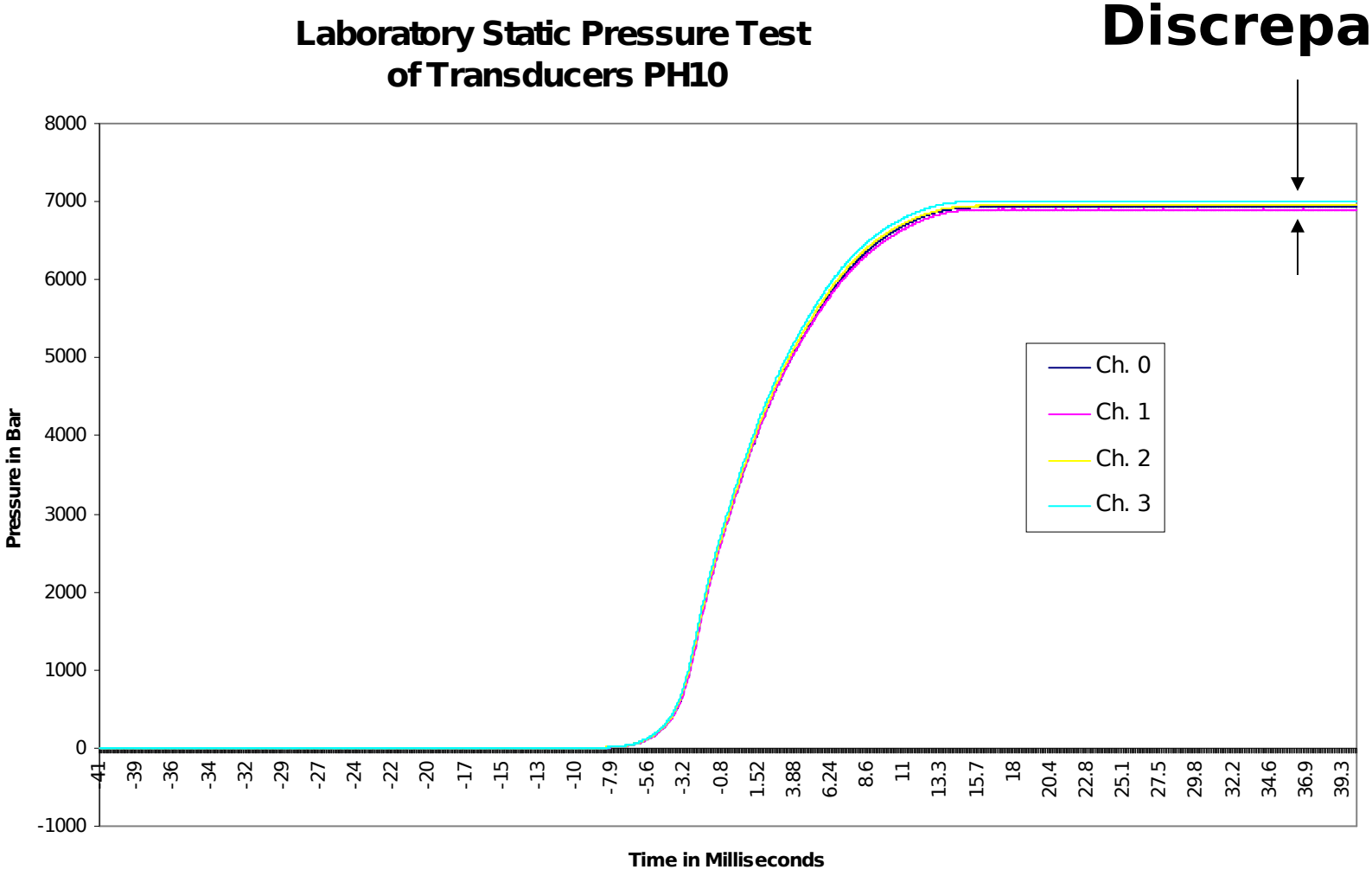

Round 13, 26Mar02, Severe Pressure Waves
Pressure in Bar
8000
7000
6000
5000
4000
3000
2000
1000
0
7
8
9
10
11
12
13
14
Time in Milliseconds
Ch.9 Scaled Strain
Ch.13 Scaled Strain
Ch.1 Quartz Piezo

# 0.5% Discrepancy

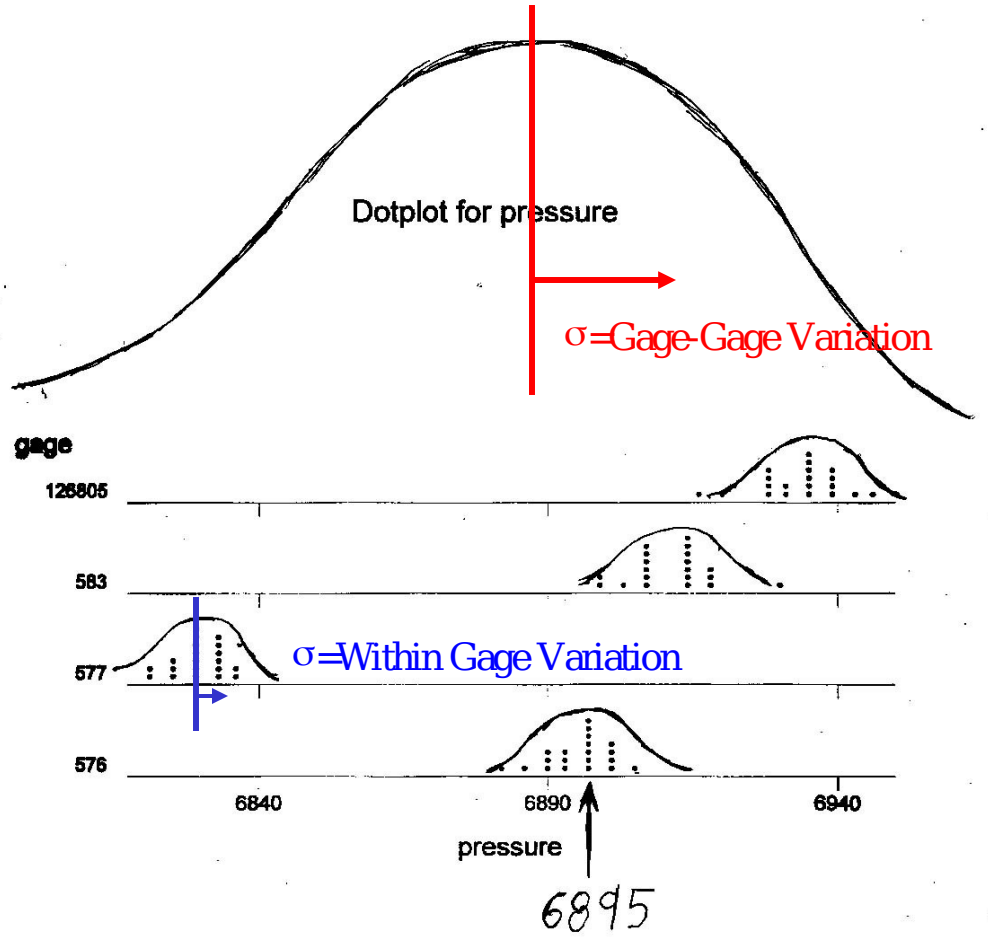
## Laboratory Static Pressure Test PH11



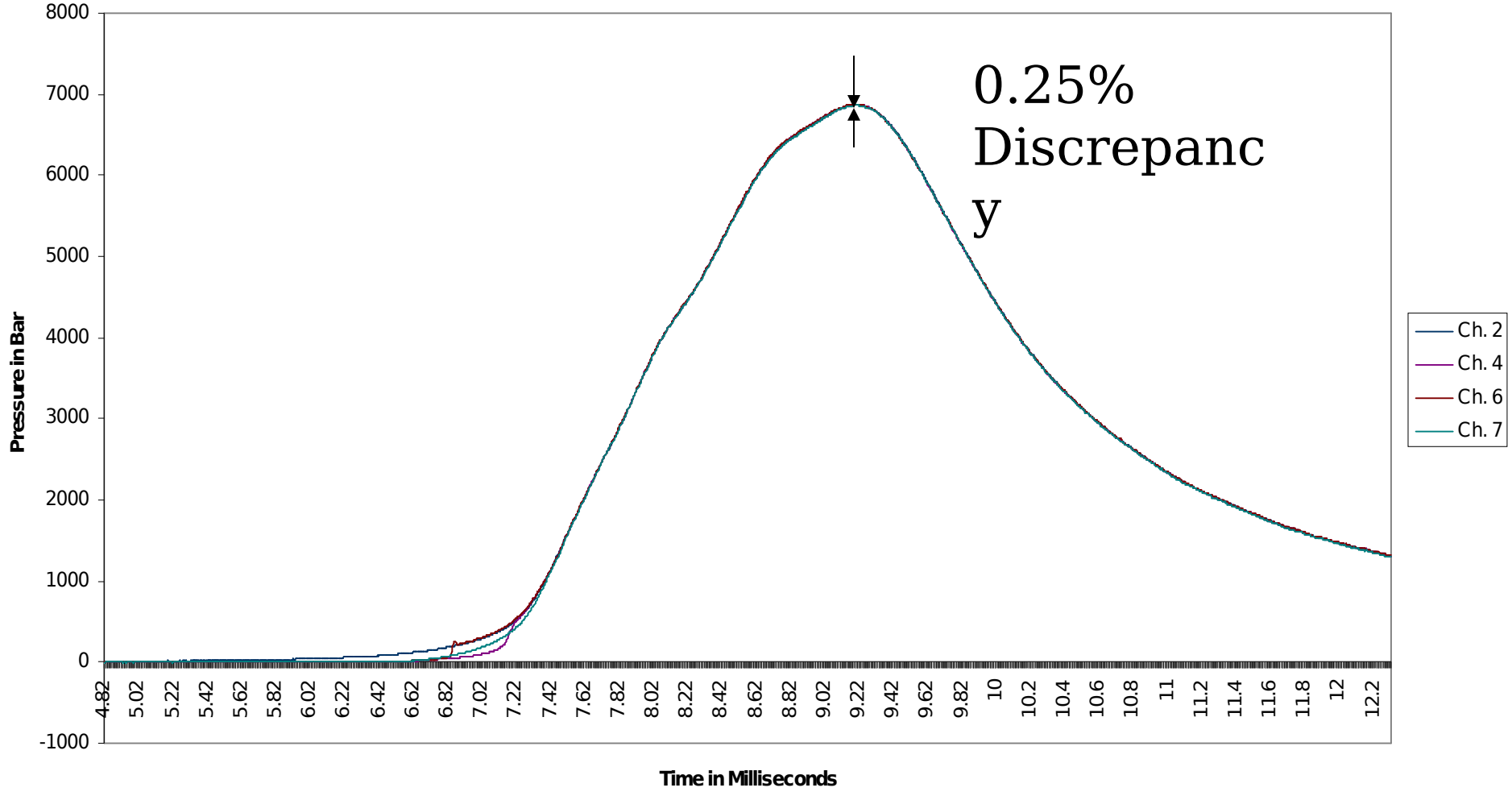
**1.9% Discrepancy**



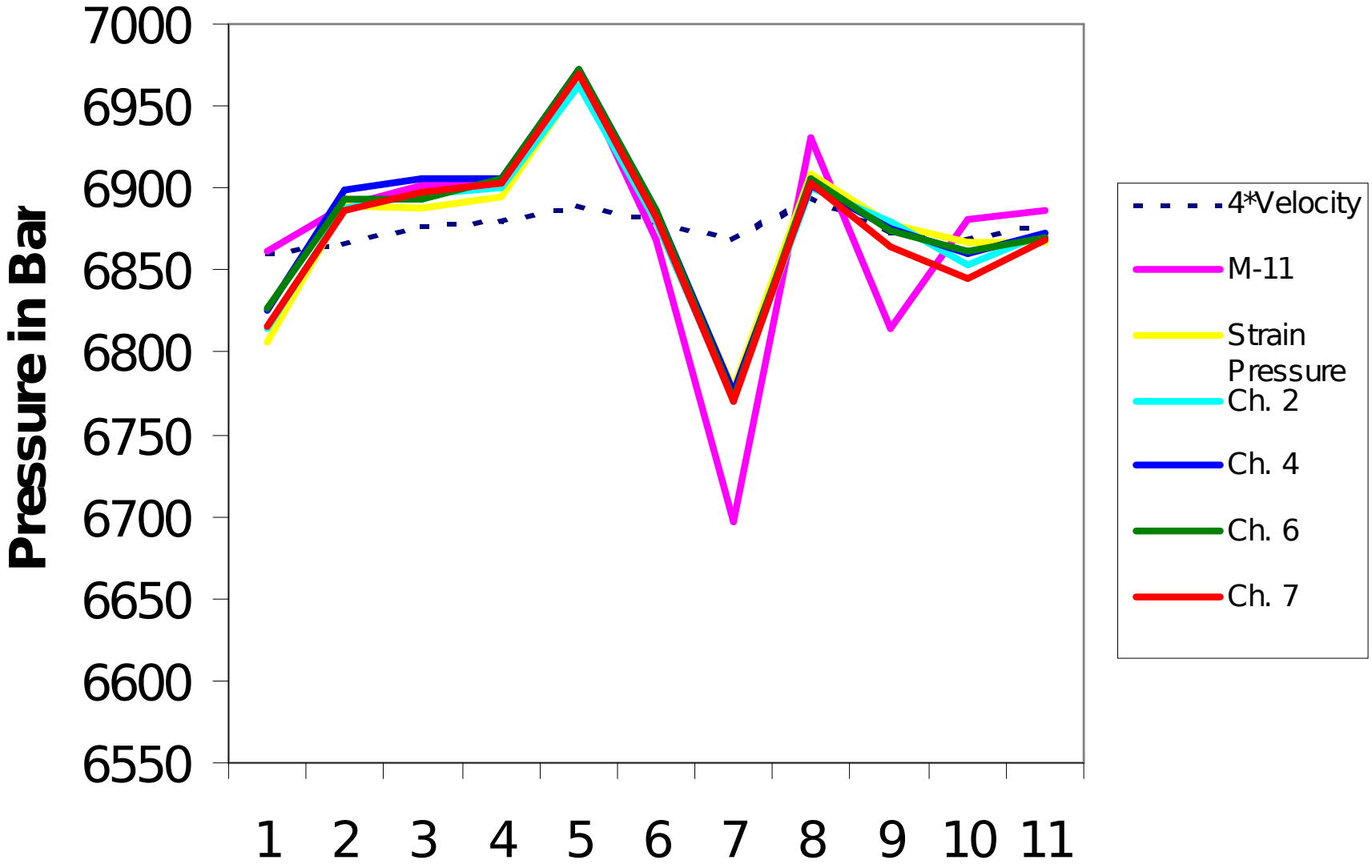
# ILLUSTRATION OF GAGE-GAGE AND WITHIN-GAGE VARIATION IN STATIC PRESSURE LABORATORY TESTING



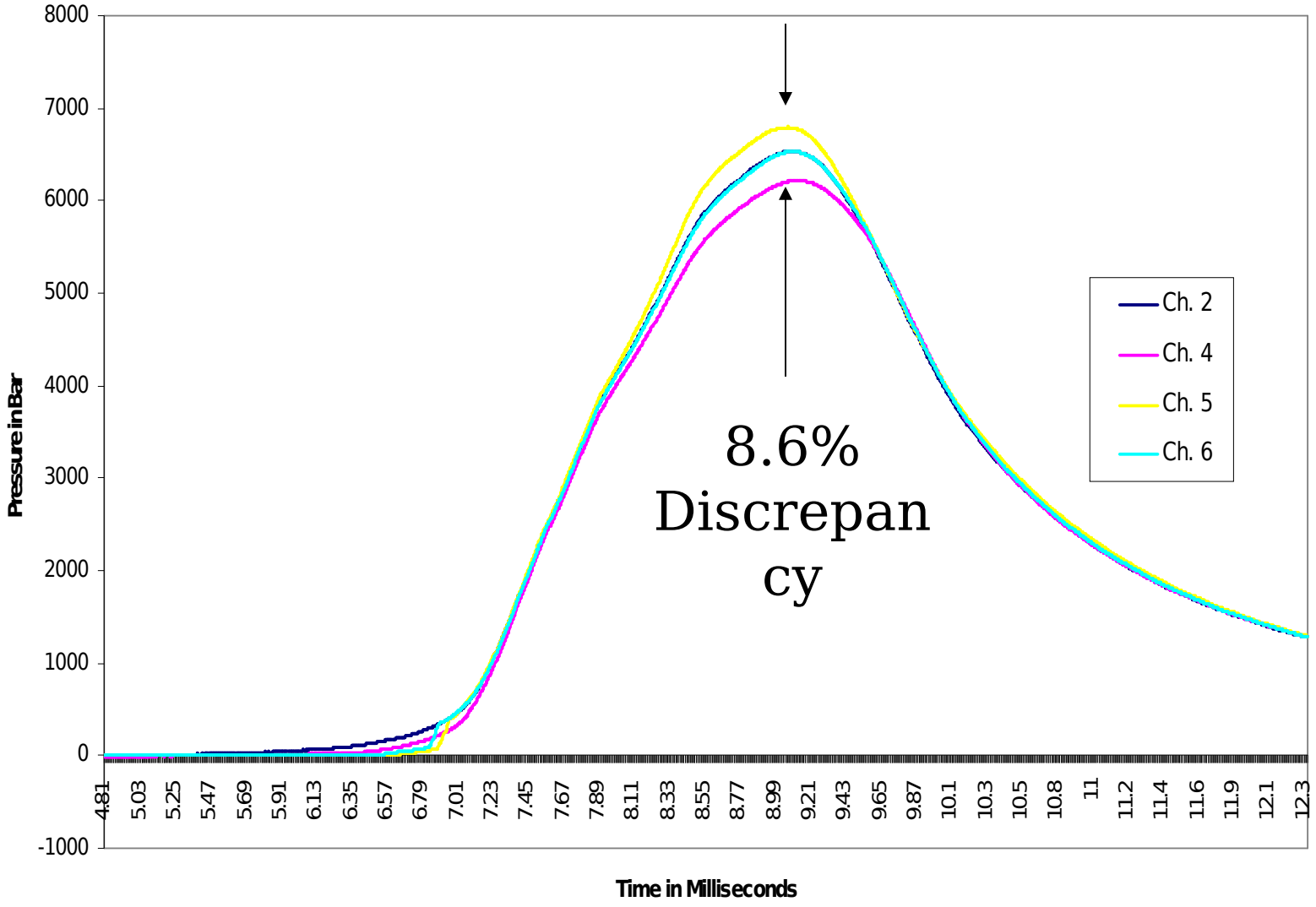
# 120mm Field Test Rd. 34, 11 Feb 02



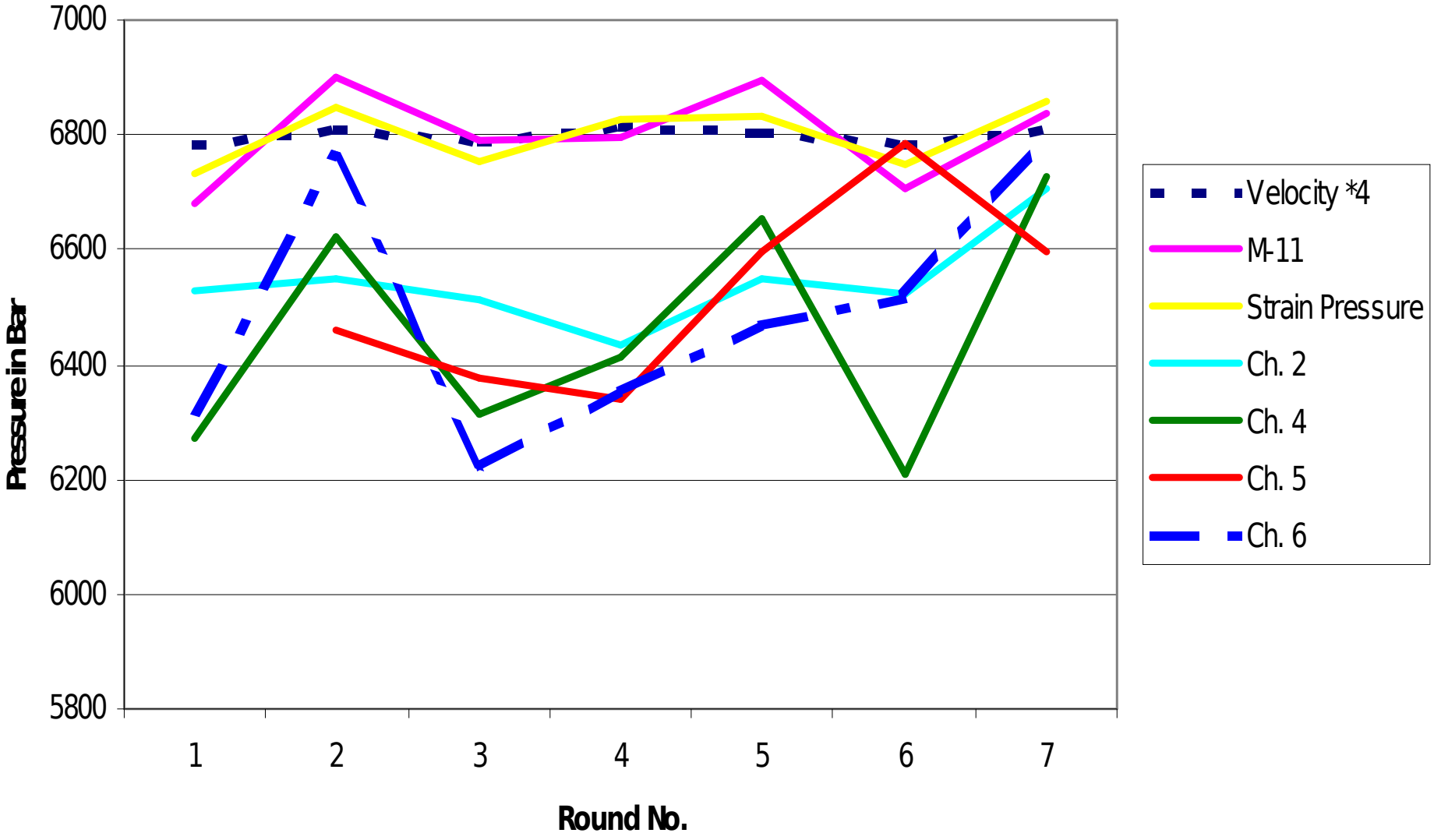
# 120mm Field Test Rounds 25-35

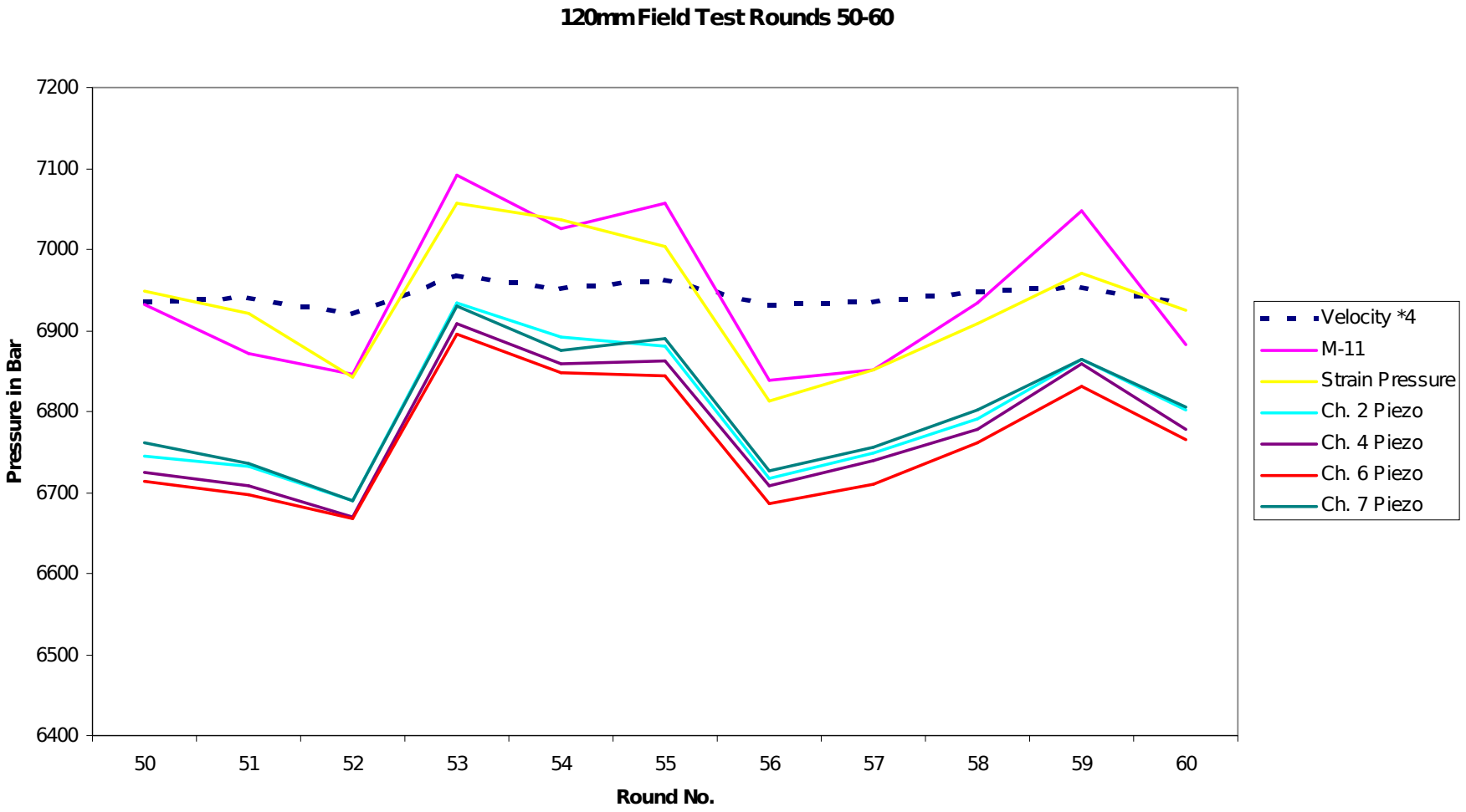


# Field Measurement in 120mm Gun



# Comparison of M-11, Copper Crusher, Velocity, and Piezo Gage Data for Rounds 1 - 7, 7 Feb 02




120mm Field Test Rounds 50-60
Pressure in Bar
7200
7100
7000
6900
6800
6700
6600
6500
6400
50
51
52
53
54
55
56
57
58
59
60
Round No.
Velocity *4
M-11
Strain Pressure
Ch. 2 Piezo
Ch. 4 Piezo
Ch. 6 Piezo
Ch. 7 Piezo

# CONCLUSIONS

- BETTER CHAMBER PRESSURE TRANSDUCERS ARE NEEDED
- USE OF CRUSHER, PIEZO, STRAIN, AND VELOCITY MEASUREMENTS IMPROVES ACCURACY
- ON ‘GOOD DAYS’, ALL MEASUREMENTS AGREE
- ON ‘BAD DAYS’, THE PROBLEM MEASUREMENTS CAN BE IDENTIFIED